THE MEASUREMENT OF THE SYSTOLIC & DIASTOLIC ARTERIAL PRESSURE WITH *PACHON'S* Sphygmometric Oscillometer.

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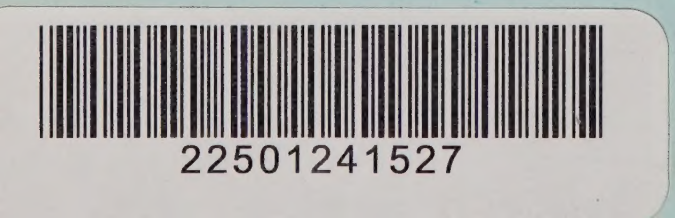

The Estimation of Arterial Pressure by the Method of Oscillations.

PRACTICAL OSCILLOMETRY.

By Dr. V. PACHON,

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I. Arterial pressure is not a definite entity in any individual. It is, on the contrary, a quantity which is constantly varying, oscillating between a **maximum** and a **minimum** characteristic for each subject, **under the same conditions of observation.**

It is therefore incorrect to speak of the amount of arterial pressure since one fixed arterial pressure does not exist.

What we have to determine and what we ought to know are the values of the **maximum** and **minimum** between which the pressure regularly fluctuates.

II. Once this simple fact has been established—which, although evident, has been ignored till the last few years—it is necessary to point out another fact which is equally evident but which has also been ignored until recently. I refer to the great importance which must be attached to an exact knowledge of the **minimal pressure.** This pressure was called by Marey **the constant pressure,** in order to emphasise the fact that it was a burden constantly supported by the arteries. Since the **minimal** pressure represents the **constant load** of the arteries, it is clear that consideration of this is more important than that of the **maximal** pressure, which only represents an **intermittent and superadded load.** Further, in regard to the heart a knowledge of the **minimal** pressure is all important.

The **minimal** pressure is the pressure exerted against the sigmoid valves during the ventricular diastole, hence its name, **diastolic** pressure. A necessary consequence follows from this fact. **The initial effort of the heart when emptying the ventricle is regulated by the minimal or diastolic pressure.** In order to open the sigmoid valves and to force the systolic wave into the arterial system, the ventricle must be able to regulate its effort to the amount of the resistance which keeps the sigmoid valves closed, namely, the diastolic pressure.

A feeble minimal pressure (7,8 cms.Hg.) will require only a **feeble effort on the part of the heart ;** if the heart can exceed this, it remains master of the situation and can accomplish its work with more energy, if necessary, for any reasons independent of the requirements of arterial resistance. On the other hand, a **high minimal** pressure (13,14 cms.Hg.) will necessarily require a **considerable effort on the part of the heart** in order to empty the ventricle, so the heart will be in a condition of distress. Hence, **although a high maximal pressure does not necessarily indicate a pathological condition** and under perfectly normal conditions may be merely the expression of the powerful systoles of a heart working energetically or uneconomically, nevertheless a **raised minimal pressure does indicate a condition of real hypertension** and exacts from the heart an extra-physiological effort in order to perform the work of emptying the ventricle or, in other words, in order to ensure the efficacy of its systole.

III. The magnitude of the minimal pressure, which is so important since it indicates the work the heart has to do and the overstrain of this organ if any be present, is best estimated by the method of oscillations. This is a unanimously recognised fact which alone would suffice to justify the choice of this method, if it were not further indicated by a fundamental principle of clinical sphygmomanometry.

THE GENERAL PRINCIPLES OF SPHYGMOMANOMETRY.

Until recent years, it has been considered a matter of **indifference** whether the pulse was examined sphygmomanometrically **below** or **at the level** of the zone compressed.

The method of Riva Rocci, the fundamental characteristic of which is to consider the **extinction of the pulse below** the level of the zone compressed as the criterion of the maximal pressure, has been employed clinically since 1896 concurrently with Marey's method of oscillations in which the pulse is examined at the same level as the zone compressed. Very dissimilar results have thus been obtained producing, instead of clearness, confusion and uncertainty in clinical observations.

It has therefore become necessary to seek the explanation of these contradictions and to establish what ought to be the procedure, that is to say, to lay down a **general law for sphygmomanometric observations.** I have shown elsewhere (*) that in Riva Rocci's method (compression of the upper arm and examination of the pulse in the radial artery) the disappearance of the pulse **below the zone compressed** was not caused, as had been thought, by stoppage of the blood flow by obliteration of the artery in the region under compression.

The disappearance of the pulse below is due to quite a different cause, namely, the **uniformisation of the blood flow** by transformation of the arterial zone compressed, at a certain moment during the compression of the upper arm, into an elastic and very distensible segment, a veritable artificial aneurysmal sac.

At the moment when the pulse is no longer felt in the radial artery **ample pulsations are present in the zone of the brachial artery under compression.** I have demonstrated this very clearly and further I have given the physical explanation and have shewn the importance of this fact as a means of appreciating the value of the method.

It has been thought, since 1896, that the disappearance of the pulse **below the zone compressed** is caused by the stoppage of the blood flow and the conclusion has been reached that the figure shown on the manometer, read at the exact moment of this

* V. Pachon. Sur l'erreur de principe de la méthode de Riva Rocci pour la détermination de la pression artérielle chez l'homme. (C.R. Soc. de Biol. 12 juin 1909, t.lxvi, p. 955-958.)

disappearance, indicates the maximal pressure. But in reaching this conclusion only one method by which the pulse might disappear has been taken into consideration, that is to say, direct extinction by means of a sufficient counter pressure.

It has been forgotten that there is another method by which the pulsating arterial wave may be suppressed : it may be **absorbed or damped down** during its course and lessened or be even no longer perceptible below, just as may happen under the influence of an aneurysmal dilatation.

At the level of an aneurysm a strong pulsation is seen at each systole of the heart—(**an ample pulsation** as in the zone of the brachial artery under compression)—because the variations in pressure which give rise to it are multiplied by a large surface ; but the pulsation being **absorbed** by the distensible aneurysmal sac (Marey) is by this means **lessened** or even **lost in the blood stream below**. There is **not a stoppage, but a uniformisation of the blood flow** beyond the aneurysm. As regards the disappearance of the pulse below the effect produced is merely the same. The same reasoning may be applied to what occurs in Riva Rocci's method, namely **disappearance by damping down,** that is to say, **uniformisation** (and not arrest) of the blood flow.

In Riva Rocci's method, and one cannot insist upon this point too often, the **upper arm is compressed,** while the pulse is **felt at the wrist** or in the forearm (which in essence is the same thing). The first result of this compression of the upper arm is to exert pressure on the outer surface of the brachial artery and thus to produce equilibrium between the external pressure and a portion of the pressure which is supported by the inner surface of the artery.

This compression, and in fact **any compression below the maximal pressure** of the blood in the artery, **tends to relax** this segment of the brachial artery which previously was in a state of distension.

As a result this arterial segment, normally almost inextensile (like any distended artery), is transformed into a zone of less resistance, that is to say, into a zone which is very distensible.

This distensible sac acts just like an artificial aneurysm. It **absorbs** or **damps down** the pulsatile wave by means of its elasticity ; **the pulse disappearing below through uniformisation of the blood flow** which continues beyond the distensible sac in a regular manner without interruptions. Therefore, because the disappearance of the pulse below the region compressed is due to quite a different cause than to the stoppage of the blood flow by obliteration of the artery, the amount of the counter pressure above which produces the extinction of the pulse below has no relationship to the maximal arterial pressure.

This explanation of the phenomena which take place in Riva Rocci's method has the advantage of explaining **simply and completely** two well known peculiarities of this method : (1) the variations in the numbers obtained which occur with variations in the size of the brachial armlet (the absorption capacity of which increases and diminishes with its size); (2) the lowness of the figures representing the maximal pressure (10,11 cms.Hg.) obtained with this method in a normal subject. It is this which led G. Weiss to say " I have seen Mr. Pachon's experiments and I am convinced that the explanation which he has given us is the true one. It is just what was required to be discovered."*

To repeat, since there is no accord between the examination of the pulse **below** and **at the level** of the compressed zone, the examination of the pulse below the compressed zone is an inexact criterion in sphygmomanometric readings. **The examination of the pulse at the exact level of the compressed zone must alone be used systematically in clinical sphygmomanometry.** My researches have therefore established the general principles of sphygmomanometry. The determination of these principles has an extremely important corollary in practice. **Marey's method of oscillations is the method which should be used.** A standard has therefore now been established for sphygmomanometry.

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* C.R.Soc. de Biol. June 12, 1909. Vol. LXVI p. 958.

THE CORRECT CONDITIONS FOR USING THE METHOD OF OSCILLATIONS.

THE SPHYGMO-OSCILLOMETER.

I have shown that the correct use of Marey's method requires two conditions which up till now have not been realised practically: great sensitiveness and, what is even more important, constant maximal sensitiveness of the instrument registering the oscillations. Great sensitiveness is required in order to obtain the necessary clearness in differentiating the

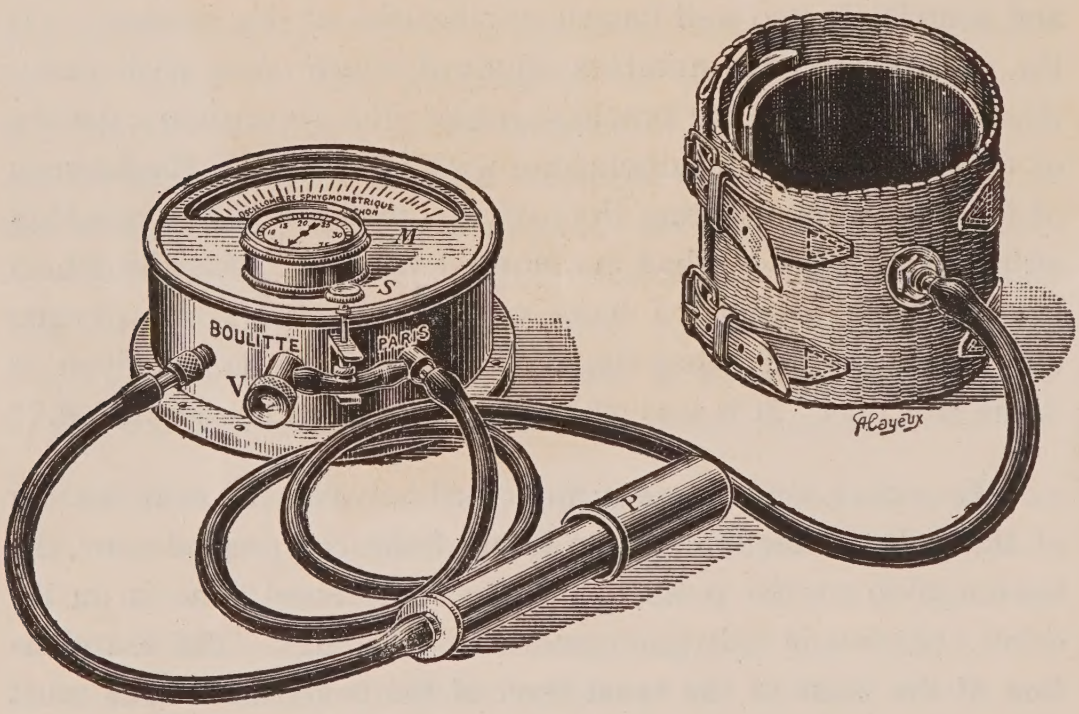

Fig. 1. The Sphygmo-Oscillometer.

oscillations and to facilitate the ready appreciation of the **commencement** and **termination** of the phase of increasing oscillations, which indicate in Marey's method the maximal and the minimal pressure. Constant maximal sensitiveness is required, for it is evident that there can be no exact comparison of the oscillations obtained under the different degrees of pressure, unless the sensitiveness of the instrument when working under these different pressures is constant.

The manometers and sphygmoscopes generally in use do not fulfil these requirements.

Having thus enunciated the terms of the problem, I have obtained a **simple** and **complete** solution by means of an instrument which is based on an entirely original principle, the **Sphygmo-oscillometer.**

This instrument, constructed on new mechanical lines, is the first realisation of an apparatus possessing elasticity with a coefficient of resistance which is not only constant but practically negligible as well, no matter what may be the level of pressure at which it is required to work in order to show the variation of pressure in any system with which it is connected.

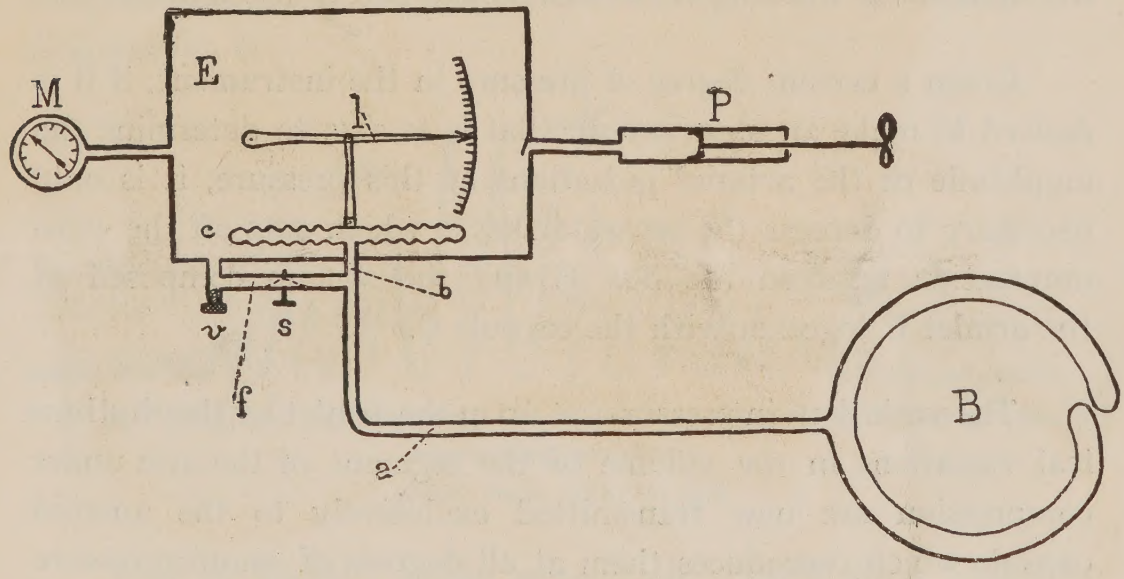

Fig. 2. Schema of the Sphygmo-Oscillometer.

Within a rigid and hermetically closed metallic box E is placed an aneroid capsule c. The metallic box E, the aneroid chamber C and the armlet B communicate with one another normally by means of the three-way channel f.b.a. Any desired pressure can be obtained throughout the whole system by means of the pump P ; the pressure obtained is given by the manometer M ; an escape valve V allows the existing pressure to be reduced at will. Hence it will be seen that any pressure which is exerted on the inner surface of the capsule C is compensated by an exactly equal pressure exerted by the air under pressure in the metallic box on the outer surface of this capsule.

At no instant, therefore, are the walls of the capsule (which constitutes the oscillometer properly so-called) **distended** whatever may be the degree of pressure inside the entire closed system. This pressure which has been produced by the pump P may be 5, 10, 15, 20 or any value *n* cms. of Hg. If the instrument be left alone, the registering needle of the oscillometer remains motionless, even if pulsations are occurring in the armlet B, because these pulsations are transmitted both to the internal surface (via B) and to the external surface (via the metallic box) of the capsule C. Thus the state of equilibrium which exists on both sides of C produces immobility of the capsule.

It is therefore necessary to introduce a means by which the dynamical working of the instrument can be brought about.

Given a certain degree of pressure in the instrument, if it is desired to make an observation, that is to say, to determine the amplitude of the arterial pulsations at this pressure, it is only necessary to depress the **separator key** S which cuts off the communication between the box E and the system composed of the armlet B together with the capsule C.

The variations in pressure set up in the armlet by the rhythmical variations in the volume of the segment of the arm under compression are now transmitted exclusively to the aneroid capsule which reproduces them at all degrees of counterpressure with **constant and maximal sensitiveness,** because the **tension** of its walls, no matter what the pressure may be, **is always nil** until the separator key is depressed.

Further the large capacity of the box E in comparison with the small volumetric changes of the capsule C will prevent any appreciable variation of the pre-existing pressure ; in other words, the capsule C, constantly at zero, moves in a space relatively infinite in comparison to its own volume.

This last condition is equally indispensable in order to realise the conditions required for the working of the oscillometer and further makes it absolutely original.

Besides its use as a sphygmomanometer the oscillometer is also, on account of its great sensitiveness, a practical instrument for **studying arterial pulsations** and **appreciating the cardiac impulse,** and it is excellently adapted both for research and for clinical demonstration especially in connection with the modern problems concerning work done by the heart.

IV.—PRACTICAL OSCILLOMETRY. CRITERION OF THE OSCILLATORY METHOD.

On compressing a segment of a limb with a pressure of from 0 to 20 cms. of Hg., for example, and then progressively relaxing the pressure, pulsations will be observed as shown in the annexed diagram fig. 3.

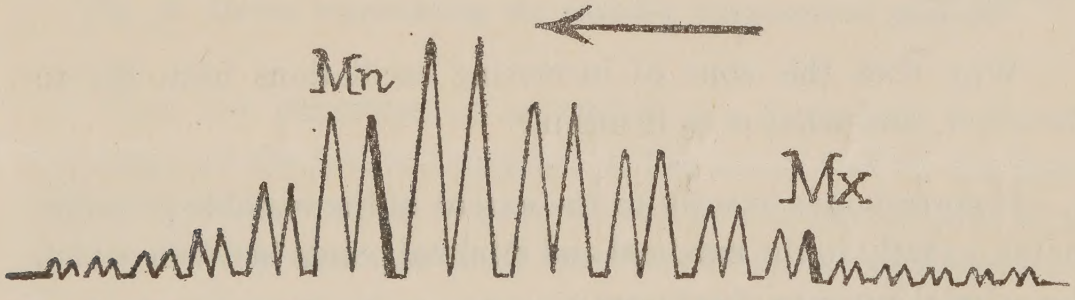

Fig. 3. Diagram representing the pulsations of a limb under gradually decreasing pressures.
Read from right to left.

This is Marey's initial experiment (1876) from which is derived the method of oscillations. This experiment of Marey comprised two **fundamental observations.** The first is that extinction of the pulse is not necessarily produced under the influence of the compression.

Three things may happen :—

(a) the pulse may be extinguished at a relatively low degree of pressure ;

(b) the pulse may disappear only at a fairly high degree of pressure (25, 30 cms. of Hg.) ;

(c) thirdly the pulse may not entirely disappear even under a very high pressure. This last case is shown in fig. 3.

Therefore in Marey's method there is no need to pay any attention to extinction of the pulse.

The criterion of the maximal pressure is not shown by the disappearance of the pulse in the method of oscillations.

Hence, if, as has been suggested at times, by this method a super-estimation of the maximal pressure is obtained, it is because this point was wrongly sought in the extinction of the pulse.

Marey's method has its own criterion which is absolutely independent of that of any other method. **This criterion is afforded by the zone of increasing oscillations** which are seen between Mx and Mn, commencing at a certain point under the influence of the gradually diminishing pressure. This is the second characteristic of Marey's experiment which must be considered.

Why does this zone of increasing oscillations from Mx to Mn occur, and what does it mean ?

It corresponds exactly to the extent of the variable pressure, that is, exactly to the **maximal** and **minimal** points between which the arterial pressure fluctuates.

On what will depend, at any moment, the size of the pulsation in the compressed limb ?

On two elements : on the one hand, the **excess of pressure inside** the artery compared to the pressure exerted on the outer wall ; on the other hand, the **time during which the excess of intra-arterial pressure** over the external counterpressure will be manifested.

When the pressure (14 cms. of Hg., for example), is just below the maximal pressure in the artery (15 cms. of Hg., for example) the walls, which were flattened together under the influence of the higher pressures, will now be enabled to come apart on account of the excess of internal pressure but only for a very short space of time because it is only during a very short period $t\,t'$ that this excess of pressure will exist.

Under a pressure of 13 cms. of Hg. the walls of the artery will separate **further and for a longer time ;** under pressures of 12,11 cms. of Hg. the walls will come apart **still further and for a still longer period,** because the excess of internal pressure over the external pressure which is being applied to the artery will exist for an ever increasing period of time.

This will easily be seen on referring to fig. 4.

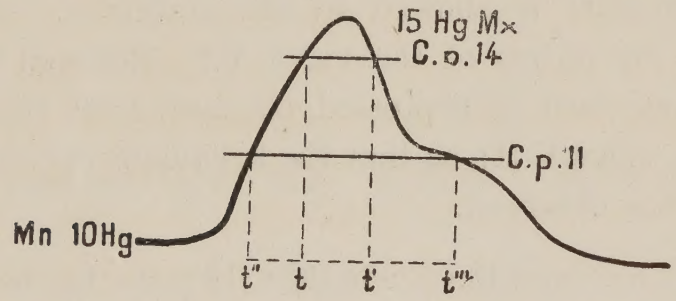

Fig. 4. Curve representing the variable intra-arterial pressure.

Thus the **pulsations of separation** are dependant both on the excess of the internal pressure in the artery and on the time during which this excess of pressure will be manifested, and they will **continue to increase** until the counter pressure is equal to the internal constant or minimal pressure (10 cms. of Hg. for example).

Then the walls of the artery will no longer be flattened together at any time and **pulsations due exclusively to distension** will alone be present, pulsations which are less than those caused by the coming apart of the arterial walls and which are represented by the last increasing pulsations of the zone Mx-Mn (fig 3).

The zone of increasing oscillations, under the influence of the gradually decreasing counterpressure, represents therefore exactly the **extent of the variable pressure** (10 to 15 cms. of Hg. for example) which the artery undergoes. The limits of this zone represent the **maximal** and **minimal** limits of this pressure. In other words, **the commencement of the increasing zone** Mx indicates the **maximal pressure ;** the **termination of the increasing zone** Mn indicates the **minimal pressure.**

METHOD OF USING THE OSCILLOMETER.

The radial armlet is placed on the subject's wrist, and the pressure is raised by the pump P until the manometer M shows a pressure undoubtedly higher than the normal maximal pressure (20 cms. of Hg., for example).

The pump is now discarded.

The pressure is allowed to fall gradually, centimetre by centimetre, by means of the valve V.* Between each fall the separator key must be depressed, the same hand being also used to open the valve V (1), so that the behaviour of the oscillometer needle may be observed.

It is of no importance whether the pulse has been abolished or not. As long as the pulsations remain equal to each other there is no need to pay attention to them.

As soon as the differentiated pulsation Mx, which **marks the commencement of the zone of gradually increasing oscillations,** is seen, the manometer M is read.

The pressure at this moment is the **maximal pressure.** The commencement of the increasing zone, marked by the pulsation Mx, may be controlled by the fact that the pulsation which immediately follows Mx has a greater amplitude. Thus both the pulsation which precedes and that which follows Mx serve as controls. The great sensitiveness of the oscillometer renders this reading still more precise. The pressure is then progressively lowered ; the zone of gradually increasing oscillations is traversed and the observer is enabled to study in a remarkable way, the characters of the pulse both as regards its rhythm and as regards its form and amplitude. The first diminished oscillation Mn following on the largest oscillations corresponds to **the minimal pressure.** The determination of the maximal and minimal pressures should be done in less than a minute.

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* It is most important never to touch the valve *v* at the same time as the separator key *s*, and in order to avoid this it is better to work the key and the valve with the same hand.

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